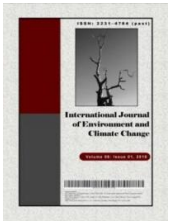

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"Green Building": A Step towards Environmental and Economic Construction

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Authors' contributions

This work was carried out in collaboration among all authors that is KS and RVS under the guidance of author RV. We all performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors KS and RVS managed the analyses of the study. Author RV managed the literature searches and helped to a lot as a guide. All authors read and approved the final manuscript.

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ABSTRACT

The purpose of this article is to provide planners with an introduction to the concept of green buildings and building assessment systems and to identify and explore the major themes in the literature as they relate to planning. Green building is one of the measures that has been put forward to alleviate the remarkable impacts of the building stock on the environment, society and economy. GRIHA (Green Rating for Integrated Habitat Assesment) is a rating instrument that helps individuals evaluate their building's efficiency against certain benchmarks that are acceptable nationwide, it evaluates a building's environmental efficiency over its entire life cycle holistically. This paper reports a critical review of the GRIHA rating system and incentives provided by GRIHA in India, techniques, and methods for construction of the green building, financial aspects of the green building. The efficiency of different environment-friendly models is broadly discussed in this study. The purpose of this paper is to explore the benefits of green building in order to proceed towards sustainable construction in the future.

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1. INTRODUCTION

The buildings which reduce the negative impact and can create a positive impact on the climate and natural environment with its design, construction are known as green buildings. The main motive of green building is to improve the quality of life and preserve natural resources.

Building Industry is one of the industries which is responsible for demolition waste and greenhouse gases. The lifecycle of the building has a major impact on the environment. The real-estate and construction sector has a share of 32% of global energy usage [1]. Due to the construction and operation of buildings natural resources are depleted such as groundwater, forest, water, and energy. Nearly, 40% of global CO2 is emitted from the buildings, India comes at 144th position in CO2 emission rating [2]. It is estimated that by 2035 the carbon emission of buildings will reach up to 42.4 billion tonnes. Construction without concrete is hard to imagine, it is predicted that the production of cement will reach up to 5 billion metric tons by 2030 which is a 40%increase from the current consumption [3]. Around 30,000 tons of carbon is dumped into the atmosphere from the cement factories in every eight minutes. [4] Cement industry generates about 7% of CO2 into the atmosphere, producing 1 ton of Portland cement causes the release of about 1 ton CO2 into the atmosphere. Over 1 trillion gallons of water are consumed by the concrete industry worldwide, which does not even include the curing water and wash water. Disposal and demolition of any concrete structure, pavement inaugurate another atmospheric problem [5].

Buildings consume a large amount of nations electricity, material, water and generate a huge amount of waste in our environment. The solution to these problems can be reduced by the construction of a green building.

The construction and operating of homes, offices, commercial buildings contribute around one-tenth of the global economy, due to construction, 40% of material flow enters in the world economy [6]. According to the prediction made by the International Energy Agency, the commercial and institutional buildings will rise 2 times by 2050.

The market of green construction is growing rapidly because in green building use of energy, water, and other natural resources can be efficiently performed. Renewable energy such as solar energy can be used, pollution reduction measures enable re-use and recycling of the waste product [7]. It helps to create a good indoor environment which has a positive effect on health and the design evolved in making of green building which helps to adapt to the changing natural environment. As compared to conventional building the thermal and visual comfort of a green building is much higher [8]. Green building also helps to control construction and demolition waste [9]. Prefabrication technologies help to reduce the amount of construction and demolition waste [10]. Prefabrication technologies also reduce construction cost [11].

Most of the people are not adopting the concept of green construction because they think that the construction of a green building is costlier than conventional buildings which are a myth. The cost of green construction is high but there are lots of financial benefits for the long term.

2. DIFFERENT NATIONAL AND OTHER PROPRIETARY SYSTEMS

The organizations such as World Green Building Council which was founded in 2002, aims to reduce the global temperature rise by 2 degree Celsius, reduce the emission of CO_2 from building and construction sector by 84 giga-ton and the net emission of all the building must be zero.

LEED, (Leadership in Energy and Environmental Design) is the most commonly used green building rating system in the world which was developed by the US Green Building Council, it aims to help the building owners and operators to be environmentally responsible and use resources efficiently. The rating system has been used in popularising the green building design. The green designs are set in the specific social context, therefore most of the country uses their own national rating system based on different concerns. In USA energy consumption in heating is a major concern, So the LEED-USA system has a high priority for energy efficiency. In Hong Kong, indoor environment quality also requires minimum percentage points for keeping the highly urbanised environment [12]. Therefore, India has developed its own green building rating system whose major concern is to work on the

emerging technologies and building practices to be followed.

Few national green building councils are:

1. LEED – US Green building council. (Leadership in Energy and Environmental Design)[13].

2. BREEAM-UK (Building Research Establishment Environmental Assessment Method)[14].

3. BEPAC-Canada (Building Environmental Performance Assessment Criteria) [15].

4. GRIHA-India (Green Rating for Integrated Habitat Assesment) [16].

3. GRIHA RATING SYSTEM

GRIHA (Green Rating for Integrated Habitat Assessment) is a green building rating system of India which was developed by TERI (The Energy and Resources Institute). About 1200 projects are registered in GRIHA covering approximately 70 million sqm of area. It has 8 aspects that cover 34 different benchmarks of ratings.

All these benchmarks are represented in the flow chart given below (Fig.1).

These 34 criterions have been allotted 104 points which are used for the evaluation of any building, to attain at least one-star rating the building must have 50 points. On the basis of points scored out of these criterions ratings of buildings are tabulated below (Table. 1).

4. TECHNIQUES AND METHODS FOR CONSTRUCTION OF GREEN BUILDING

There are various methods, design and techniques by which any building can be made green, most commonly used methods for green construction are discussed below.

Civic Tree Plantation: As the world population continues to grow, the population density is gradually increasing in the urban areas this is also because of the population shift from the rural area to urban area which is known as urbanization. The rapid expansion of urbanization is detrimental for forest and the green areas around the city, an increase in pollution, extreme climatic changes and a decrease in the availability of natural resources. Due to urbanization, the emission of greenhouse gases such as CO2 is increased, this problem can be temporarily reduced by planting trees in the urban areas and to attain long term reduction the population of trees must be constant. Over the lifespan of the tree, several tons of CO2 is absorbed by the trees for its growth [17]. The strategic placement of trees can help to reduce the heat island effect because of evapotranspiration. Nowadays green roof is one of the trending method used to reduce the heat island effect in the cities with high rise buildings. A green roof is a building roof where the vegetation is planted over a waterproof membrane designed as per the load capacity of the roof. The green roof will reduce the cooling energy consumption of air conditioning buildings because of the thermally insulated structure of the roof preventing excessive solar heat. Sedum plants and Turfgrass are the most commonly used plants for the construction of the green roof [18]. By the increased plantation of trees, the average day time temperature of a city is decreased due to which the electric energy consumption(use of electric appliances) and CO2 emission is reduced. Plantation of about one million trees will reduce the atmospheric CO2 by about 1 million tons of CO2 over the next 35 years [19].

Table 1. Points scored with the rating

Points scored	Rating
50-60	1 star
61-70	2 star
71-80	3 star
81-90	4 star
91 and above	5 star

Green Concrete: In the field of construction, Portland cement concrete is widely used which is substantial because Portland cement concrete emits greenhouse gasses such as CO2 in the environment, as we know that 40% of global CO2 is emitted by buildings that can be reduced by the use of green concrete. The large amount of CO2 is emitted while manufacturing Portland cement because of the heating of limestone and clinker at a large amount of heat.2We can decrease the CO2 emission by replacing some amount of Portland cementitious material with Fly ash [20]. Fly ash is a residue of coal combustion which is an excellent cementitious material. Fly ash is less expensive from Portland cement because it is the by-product of coal combustion that would be a waste product to be disposed of at great cost.

The study of green concrete by replacing some amount of cement content by Flyash has a tremendous effect on the physical and chemical properties of concrete which are as follows: [21]

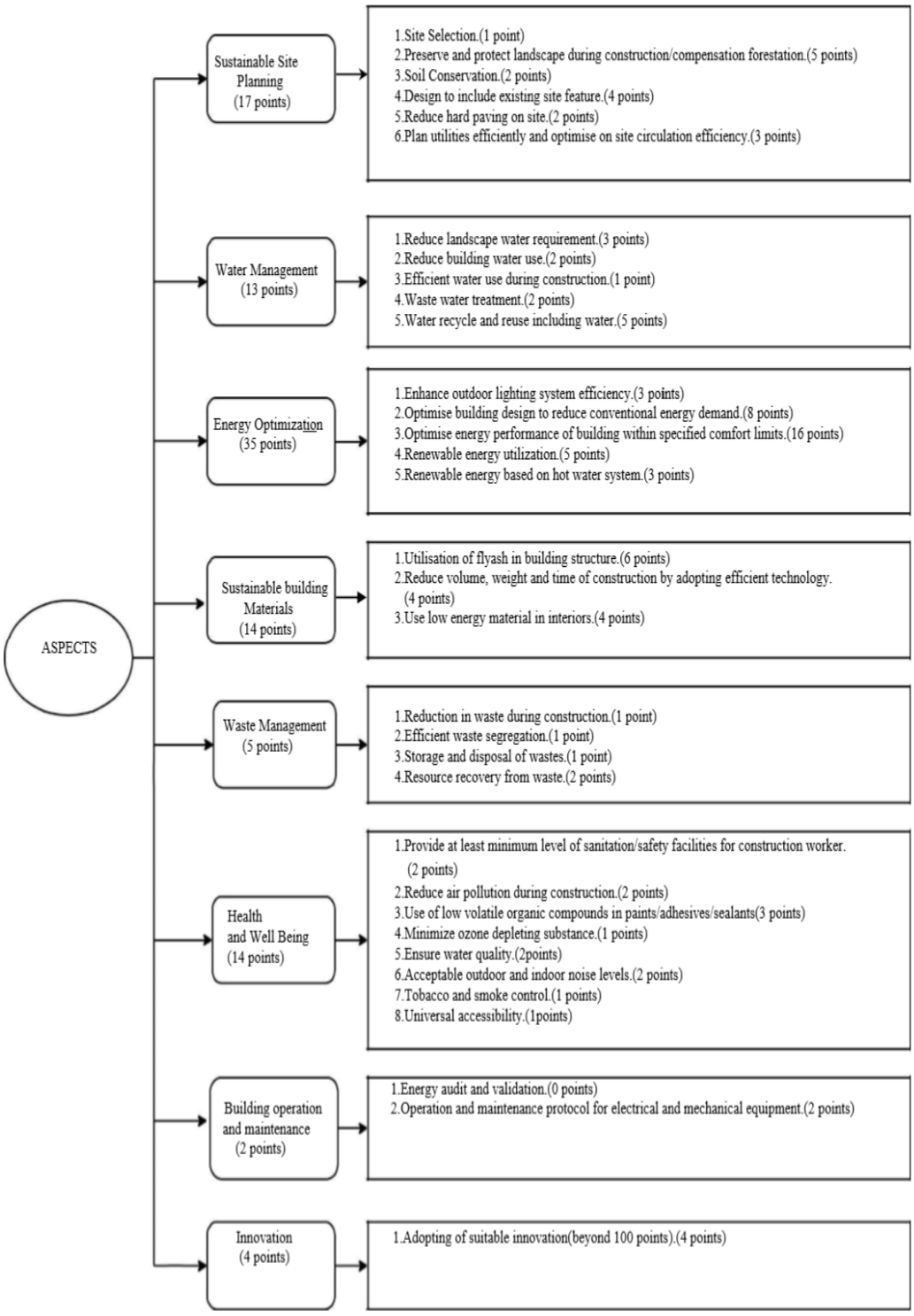

Fig. 1. GRIHA rating system

- Effect on workability- Replacing fly ash as a cementitious material increases the workability and reduces the water required to attain consistency.
- Effect on Bleeding- It reduces the water content due to which bleeding is reduced but at the same time the mobility of the mix is increased, due to which the setting time is delayed, which increases the bleeding.
- Effect on setting time- It has both chemical and physical effect.

    1. **Physical effect:** As the specific gravity of fly ash is less than Portland cement the replacement of cement on equal weight means that the volume of fly ash is increased.
    2. **Chemical effect:** It can affect the hydration process because some fly ashes react within itself.

- Effect on durability- Replacing with a considerable amount of fly ash increases the durability and the compressive strength of the specimen.

If the Fly-ash content exceeds by 40% in concrete at a lower temperature than it leads to slow strength development [22], the early compressive strength of green concrete is less as compared to Portland cement concrete but under high air curing the compressive strength of green concrete is much more than that of Portland cement concrete. [23] Fly ash is not only used for the purpose of saving energy but in point of fact, it also reduces the amount of landfill waste [24].

Energy optimization: Consumption of energy is one of the major factors in the growth of commercial and industrial areas. To fulfil the large energy demand, it is essential to consume energy from renewable resources for sustainable development, for fulfilling the large demand for energy health and productivity should not be compromised [25]. In India, most of the power generation is due to the burning of fossil fuels which contributes to the emission of greenhouse gases [26]. Renewable energy such as wind energy, solar energy, and biomass energy can be converted into electrical energy without emitting any greenhouse gas [27]. The energy demand of the world can be fulfilled by solar power if the needed technology is available [28]. Around 342 Wm-2solar energy is received in the earth's atmosphere out of which 30% is scattered or reflected back to space and the remaining amount of energy can be consumed [29]. The estimated solar power capacity of India by 2022 is 100,000 MW [29]. Solar Photovoltaic Plants are used to convert the direct sunlight into electricity without emitting any greenhouse gas. Nowadays it has a wider application such as power generation, heating, water pumping, desalination, etc. which has a major impact on green construction. It produces the required amount of electricity on-site and it is the cheapest source of energy. Energy loss happens through physical phenomena, radiation, convection currents, and air leak, however, energy-efficient windows are a good way to combat these processes and in the reduction of energy use. The success of energy-efficient options varies supported climate, window direction, and the way a window fits into overall home style, therefore owners ought to rigorously think about what kinds of windows best work their wants. The crystal rectifier (LED) is one in all today's most energy-efficient and rapidly-developing lighting technologies. Quality LED light-weight bulbs last longer, are a lot of sturdy, and provide comparable or higher light quality than alternative sorts of lighting. Widespread use of light-emitting diode lighting has the best potential impact on energy savings within the united states. By 2027, the widespread use of light-emitting diodes might save regarding 348 TWh (compared to no LED use) of electricity: this can be the equivalent annual electrical output of forty-four giant electrical power plants (1000 megawatts each) and a complete savings of over $30 billion at today's electricity costs [30].

Water Management: Water that has been already utilized for the domestic, industrial, commercial or agricultural use is known to wastewater. Wastewater contain large amount of organic matter and toxic chemicals which cannot be directly disposed in the environment because it may lead to water-borne diseases or degradation of natural resources, therefore, it is essential to treat the wastewater and dump only the unwanted toxic material present in it, so that the treated water can be reused for the various purpose. In India 1086 km3 water is utilized from the water resources [31] the utilized water must be reused for sustainable growth. Aerobic wastewater treatment methods are the most common methods centralized in developed countries. In a developed country like the USA, treatment can easily differ between rural and urban users with respect to their income [31].

The table is given below (Table 2) is the case study of a few Green Buildings constructed in India that have used these methods [32].

Table 2. Different energy saving techniques used in different buildings in India

Building and location	Civic tree plantation	Sustainable material	Solar plant	Waste water treatment	Other strategies used	Rating
Grape county resort, Nasik	Total of 538 new native trees was planted.	Green Concrete (fly-ash content in the range of 15-35%.)	30 kW solar photovoltaic system of capacity	STP (Sewage Treatment Plant) based on reed bed system treats 100% of sewage generated	1.Protection of 50 existing trees on site. 2.Rainwater Harvesting. 3.Use of sprinkler and drip irrigation to reduce landscape water demand. 4.Use of 50% recycled content reinforced steel. 5. Over 73.24% of total living area falls under the day-lit zone. 6.Use of eco-friendly housekeeping products	5 star
Bel academy, Bangaluru	260 new saplings were planted	Green Concrete(28% of cement is replaced with fly-ash)	The 90kWp capacity of solar Photovoltaic panel	-	1.Protection of 110 existing trees on site. 2.Adoption of native species of vegetables to reduce landscape water demand by 46%. 3.Use of low flow water fixtures and dual flushing system to reduce the building water demand by 73%. 4.Rainwater Harvesting. 5. 100% of all paints and adhesives used in the building interiors have low or zero-VOC	5 Stars
Manipal County, Bangalore	130 new trees were planted	Green Concrete(30% cement is replaced with fly ash)	150kWp solar Photovoltaic system	-	1.Protection of 22 existing trees on site. 2.Adoption of native species of plants to reduce landscape water demand by 53.28%. 3..Use of low flow water fixtures and dual flushing system to reduce the building water demand by 58%.	5 Star

Building and location	Civic tree plantation	Sustainable material	Solar plant	Waste water treatment	Other strategies used	Rating
					4.Use of solar hot water system. 5. 100% of all paints and adhesives used in the building interiors have low or zero-VOC.	
NHPC corporate office, Faridabad	Most of the existing trees were properly preserved	Green Concrete(33% fly ash content)	70kWp solar photovoltaic system	-	1.Protection of 100 existing trees on site. 2 Use of sprinkler, drip irrigation and adoption of native species of plants to reduce landscape water demand by 64.8%. 3. Use of Low flow taps and sensor-based urinals to reduce the building of water demand by 30.95%. 4.Use of motion sensor light to reduce energy consumption.	4 stars
New interim terminal building Vijayawada Airport	254 new trees were planted	Fly ash bricks were used	15kW solar Photovoltaic system	STP (Sewage Treatment Plant)with 200 KLD capacity	1.Use of low flow water fixtures and dual flushing system to reduce the building water demand by 64.4%. 2.Use of AAC blocks and rock wool insulation in the external wall for thermal comfort. 3. 100% of all paints and adhesives used in the building interiors have low or zero-VOC. 4.Protection of 6 mature existing trees on site.	3 star

5. FINANCIAL ASPECTS OF GREEN BUILDING

As we have already discussed that the major misconception about green buildings is that its cost of construction is more than conventional buildings. The conversation of cost of green construction is dominated by benefits and values of green construction because the decision-makers are in dilemma, i.e., on one hand, they want to provide facilities to enhance the organizational productivity but often they do not want to make investments in the kind of changes needed until they have proof that they will pay off. 30% of the operating cost of a building is due to electricity and water consumption when it comes to energy consumption green buildings are 25% to 30% more efficient [33]. Moreover, green building reduces the demand for water [34]. Green building gives lots of financial profit in the long term. The benefits of green building include energy and water savings, reduced waste, improved indoor environmental quality, greater employee comfort/productivity, reduced employee health costs, these features also helps to increase rent and decrease the operating cost [35].

Green buildings are 28% more efficient and generate 2% of their power on-site by photovoltaics which makes it 30% more energy-efficient than a conventional building [36]. The green features of buildings can save about 55% of energy costs as compared to conventional buildings [37]. Most people spend 90% of their time in an indoor environment only, the concentration of pollutants in the indoor environment is higher than the outdoor environment [38]. Construction focuses on the interior environment and individual performance which helps to increase the health and productivity of an individual. The indoor environment of green buildings provides higher satisfaction of thermal and visual comfort as compared to a conventional building [39].In a study found that people living in green buildings are more mentally stable and tolerant [40].1% of productivity and health is gained from buildings which are silver-rated and 1.5% of productivity is gained by gold/platinum-rated buildings and 1% increase of productivity is equal to about 5 mins per working day whereas 1.5% increase in productivity is equal to 7 mins per working day [36]. Due to healthy interior environmental quality green building enhances the ability to rent or sell space [41].

Building constructor who want green construction but don't want it to cost more than a conventional building needs to have cost and environment awareness in their minds, based on the national proprietary systems rating the government of India provide certain incentives in different states as given in Table 3 : [42].

Table 3. Incentives provided by different agencies

States	Agencies	Incentives provided
Punjab/Rajasthan /Uttar Pradesh Government	Punjab Urban Development authority/Urban development and housing department/Housing and Urban planning department.	5% additional FAR(Floor Area Ratio) is provided free of charge on buildings which are gold rated or above.
West Bengal /Himachal Pradesh Government	Kolkata Municipal Corporation/ Town and country planning department.	10% additional FAR(Floor Area Ratio) is provided free of charge on buildings which are gold rated or above.
Andhra Pradesh Government	Industries and commerce department	Offers 25% subsidy on total fixed capital investment of the commercial, industrial project.
	Municipal administration and urban development department	20% reduction on permit fee.
Jharkhand Government	Urban Development and housing department	Additional FAR is provided for Silver rated-3% Gold rated-5% Platinum rated-7%
Haryana Government	Town and country planning department	Additional FAR is provided for Silver rated-9% Gold rated-12% Platinum rated-15%

5.1 Redefining Role

The increasing experience and sophistication in the use of building environmental assessment methods have generated a number of new roles and expectations that were not evidenced in their conception and design. The papers presented in this special issue collectively suggest that in addition to continued refinement of technical and scientific underpinnings, market context and process-related factors will play an increasingly decisive role in the ongoing evolution, development and adoption of building environmental assessment methods. The formulation of current assessment methods spawned debate and investigation into the broad range of technical issues and their consequences on implementation. The papers herein have begun to chart new areas and roles that assessment methods can offer in promoting innovation and the promulgation of greener buildings: shifting the emphasis away from the product (i.e. buildings) to enhancing the process; understanding the areas and consensus or conflict between major stakeholders; the competition between voluntary assessment methods within a market; and the setting of performance targets. As these emerging roles become increasing explicit expectations, one can anticipate a fundamental reframing of building environmental assessment methods that will continue to change qualitatively the kinds of research questions that are asked, the disciplines that are involved in the research and practice, and the approaches that are necessary to support future developments and implementation.

6. CONCLUSIONS

The world is moving towards sustainable development, so in the field of construction, green building is a step towards sustainable development. It is important to recognize the benefits of green buildings so that people can overcome their psychological barrier of a misconception that green buildings are not appropriate for construction. The developing countries like India need to avoid the mistake of not using sustainable building materials and must plan to make a building more energy and water efficient which will definitely lead to the sustainable development of a country. According to the GRIHA rating of a building, different incentives are provided, which will help to gain more economical and financial benefits.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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